Outward FDI: National and Regional Policy Implications for Technology Innovation

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Abstract

A significant contributor to China's growth over the last 20 years is the 'go-out' policy, that is, for domestic firms to invest in international firms and has seen it develop a foundation of high technology industries and world leading research. We find that across China, the 'go-out' policy needs support from provincial governments in terms of human capital, basic research and infrastructure to ensure that imported technology is effectively absorbed into the local economies. This means a national strategy needs local tuning to the needs of the region. Across all provinces, we find that during the period 2006 to 2016 outward foreign direct investment (OFDI) spillovers have a significant and positive impact on technology innovation as measured by patents. OFDI alone is insufficient and may crowd out local research and development (R&D), as such, those provinces need to get to a threshold of absorptive capacity in basic, applied research supported by human capital and R&D capital stock. When the gap between a province and the rest of the world is large then OFDI could have a crowding out effect without the province supporting basic research. We test for structural changes across all provinces by classifying them by either having large or small frontier technology, the proxy for absorptive capacity. We find that the role of human capital and basic research changes substantially between small gap and large gap provinces indicating that regional policy makers need to ensure that policies are fine tuned to the stage of development in a particular region and will change over time. OFDI effects are diminished as the provinces gap reduces and this may be particularly timely in the face of China being subject to increasing trade and investment pressure internationally.

Key words: Technological innovation, government policy, OFDI spillovers, technology gap, threshold effect, basic research and applied research.

JEL classification: C24, F21**,** O32, O35, O38

1 Introduction

From 2000, the Chinese Government actively promotes a ‘go-out’ investment policy. This encourages domestic firms to invest in foreign countries and markets using outward investment funds flow in ‘exchange’ for a flow of technology and knowledge. Why? In part ‘a catch up’ and ‘go past’ the developed economies by improving productivity that promotes economic growth. The strategy intention is to increase domestic wealth creation sustainability whilst promoting foreign political and economic influence in the world for by productivity improvement is through the foreign knowhow[1] acquisition and absorption into provincial economies.

This Chinese national and international strategic policy raises important questions, such as, is the effect the same for all provinces? Or are the spillovers subject to a threshold effect determined by the current development of the provinces? The Chinese government has a problem with the unequal distribution of wealth generating activities across provinces, which has the effect of displacing populations from poorer rural areas, so over-burgeoning the infrastructure and over-populating in some areas, potentially creating the seed for civil unrest. The concentration of industry in the east has already had significant impacts on the population, environment and wealth distribution.

Internationally, China faces significant sanctions from developed countries for promoting a coordinated transfer of intellectual property from developed nations, via various means, to Chinese firms when investing or buying from China. This may limit the opportunities to gain FDI (foreign direct investment) as outlined by Almfraji and Almsafir (2014).

The 2017 World Investment Report indicates that Chinese multinationals (MNE) invested US$183bn in 2016, a substantial increase of 44% from 2016. Can we establish the motivation for this significant increase in OFDI by Chinese MNCs? Chakrabarti (2001), Mathews (2006) and Rui and Yip (2008), all give insights into some of these motivations. Developed countries, particularly the US, have responded to China’s expansion with sanctions and protections to prevent mass knowledge and intellectual property transfer[2]. Namely, to limit the impact of sanctions or other protection mechanisms by. The strategy is through the investment channel,

[1] We use the term Knowhow, in the quasi legal context, that includes all aspects of knowledge and expertise needed to make something or deliver a service.

[2] The US has recently (2018-19) imposed significant sanctions and restrictions on China, in part to limit the flow of imports.

including joint ventures and buyouts, and acquisitions. Furthermore, Chinese firms might perceive some existing gap between their technology capabilities and those they are investing in. This raises another line of inquiry on how efficient and effective Chinese firms are at transferring and utilising the technology and expertise. At a government level, an efficient process would support the Chinese growth strategy. Many other emerging economies are seeking to 'short-cut' technological development and would look to China as a model in how to achieve this, if it is efficient. This would give China some political and economic sway on the world stage.

We also need to consider investment effects domestically, specifically in technological innovation and spillovers. Villa (1990) defines technological innovative capacity as the outcomes of all corporate and individual invention. Similarly, Furman et al. (2002) as the ability to commercialise innovative technology over the long run. What impact does OFDI have on innovation? For the more traditional inward investment, Coe and Helpman (1995) clearly establish a link between inward investment flows and technological innovation. For the host country, they can take capital and advanced technology and skills to augment the existing technology (De Mello, 1999; Mariotti et al., 2015; Farrell, 2008; Almfraji and Almsafir, 2014). For the investing country, it allows foreign companies to seek new markets abroad at the cost of sharing knowhow (Mariotti et al., 2015; Farrell, 2008).

This knowhow carries the potential for spillovers into other firms (Lai et al., 2006; Liu and Buck, 2006; Keller and Yeaple, 2009). The effect is most prevalent when there is a significant technological gap between the developed country investor and developing country's firms. This is not a new phenomenon; such developments are recorded throughout history with examples from the Roman empires and other empires[3]. However, for OFDI to be a success, the reverse would need to occur, that is, capital flows outwards and technology knowhow flows inwards (Li et al., 2016a). These international interactions not only provide investment, they also provide a mechanism to close the technology knowhow gap partially through spillovers (Almfraji and Almsafir, 2014).

For our analysis we seek to answer three questions:

1. *Does Chinese OFDI boost domestic technological innovation*?
2. *Do regional differences through the technology absorption threshold affect the rate of*

[3] Although these two examples are principally exploitative, they do illustrate the point of inward investment and the transmission of technology knowhow.

OFDI spillovers and the rate of technological innovation?

3. *Do regional differences in the technology gap between a region and the rest of the world affect the technological innovation outcomes from basic and applied research and, OFDI?*

This paper contributes to the literature by developing an understanding of China's strategy to import technological knowhow and so maintain growth across all its provinces. One of the characteristics of China's strategy is to develop the provinces to a level so they can take up technological innovation efficiently. We demonstrate a threshold effect where a foundational level of development is required in the provinces prior to exploiting OFDI channels. Our innovation is that basic research, applied research and OFDI have different joint impacts on technological innovation based on different technology gaps. This influences the political decision making at both provincial and national level by determining the funding and deployment of foundational applied research. It also determines levels of infrastructural and human capital development required in the provinces.

Following the introduction, we review the existing literature, and develop the hypotheses that then leads to the methodology and framework, after a brief summary of the data, we report and analyse the results followed by the policy implications and conclusions.

2 Literature Review

To progress, developing countries use an OFDI strategy to overcome the barriers, in particular, in the transfer of knowhow from developed countries by intellectual property protection, limiting knowledge transfer and imposing sanctions on countries with low property rights protections. The prospective developing country MNE needs to go international to gain domestic advantage and overcome these international trade barriers (Wells, 1983). In the developing world it is possible for firms to substitute labour for capital investment. This allows then to undercut developed economies and enable exporting and acquisition of foreign currency. When these burgeoning MNE are threatened by sanctions or restrictions, they seek alternatives though OFDI (Chakrabarti, 2001). It is somewhat harder for developed countries to impose investment restrictions on a foreign MNE in an open market. This provides a pathway that motivates developing country MNE to gain transfers of knowhow though investment (Child and Rodrigues, 2005; Rui and Yip, 2008; Luo et al., 2010; Ramasamy et al., 2012; Chen and Tang, 2014). China, as with other developing countries such as India, continues to encourage OFDI at the governmental level.

The strategic interests of Chinese state-owned enterprises (SOE) and private firms may be different, hence their investment decisions divergent (Ramasamy et al., 2012). Many Chinese SOE tend to invest in access to increasingly scarce natural resources thereby securing the supply for their industries and potentially giving political and economic power on the world markets. This draws many similarities to the European colonial period and the US involvement in Oil and energy resources in the 20th century. These tend to be in challenging political environments where past 'occupiers' have suppressed whereas China is seen more as a 'partner' in development bringing a level of economic and political stability (Rui and Yip, 2008). However, private OFDI tends to focus more on knowhow capture from secure developed nations though either technology acquisition or process, management and production performance knowhow (Chen and Tang, 2014). This provides the first motivation, namely, empirically evaluating the impact of such knowhow acquisition on Chinese domestic technological innovation.

One of the core issues facing China's OFDI strategy is; does it have enough absorptive capacity to fully exploit the acquired technology and knowhow? Much of this capacity is dependent on a spillover effect into firms that have the knowledge and expertise to exploit both technology and knowhow efficiently (Cohen and Levinthal, 1990; Breschi and Lissoni, 2001; García-Morales et.al, 2008). This is reliant on how well knowledge is managed and disseminated (Zahra and George, 2002; García-Morales et al., 2008), the human capital in the form of education, skills, capabilities and abilities of people to take on and utilize technology and knowhow (Glass and Saggi, 1998; Zahra and George, 2002; Comin and Hobijn, 2004) to utilize in R&D though to production (Mowery and Oxley, 1995). This implies that there must be a level of domestic development to ensure that the gap not to be so wide as to be a barrier to efficient take up of knowhow, that is a threshold of human capital, technology and R&D capability for efficient knowhow transfer for a given level of developed world technology and knowhow being imported. There are several other factors that interplay with efficient absorption including openness (Comin and Hobijn, 2004; Lai, et al., 2006), financial market efficiency (Hermes and Lensink, 2003; Alfaro et al., 2004) and the rule of law. These factors are somewhat subservient to the main factors above. We empirically analyse the inward foreign direct investment (IFDI) and OFDI spillovers by using human capital, technology and R&D capacity's impact on technology progress to determine if a threshold effect exists.

Commonly, a technology gap index is there basis for absorptive capacity in IFDI spillovers analysis, hence we apply the same index to OFDI. A wide technology gap is most likely to encourage imitation that can lead to a narrowing of the gap and improve absorptive efficiency, hence capacity (Verspagen, 1992; Glass and Saggi, 1998; Girma et al., 2001). Most empirical studies are at a national level (Liu et al., 2005; Buckley et al., 2007). This may lead to variable results due to the limitations in aggregation at a national level that largely compromise any conclusions (Sonnenschein-Mantel-Debreu , 1973-6).

Each firm has its own development path, ownership and technology gap and individual firm micro level data for Chinese firms is not available. This leads us to using provincial level data to describe differences within regions. Spillovers are both geographically constrained and industry classification specific in nature minimizing the distance for knowledge transfer (Hamida, 2013). This tend map closely to the Chinese regions trends to specialize particular industries. Although this does not fully overcome some of the objections to aggregation, it does address the main issue of national level aggregation and maps closely to the Regional Innovation Systems Theory (Asheim et al., 2011). Furthermore, provincial level data is readily available over a reasonable time period for most of the provinces. This is enough to give insight into absorptive capacity threshold effects for comparisons at both regional and provincial level. Li et al. (2016a) and Piperopoulos et al. (2018) claim that OFDI boosts product innovation and facilitates productivity gains mapping technological innovation and absorptive capacity. The labour force tends to be regional in nature and with infrastructural development then OFDI spillovers have positive impact on regional technological innovation (Wang and Blomström, 1992; Crespo and Fontoura, 2007; Hamida, 2013; Rojec, 2018). This supports the view that provincial data is sufficient for our purpose.

There is a contradiction in the literature regarding the effectiveness of OFDI. Edamura et al., (2014) find that at firm level data supports the hypothesis that firms achieve their goals with OFDI whereas Bai (2009) concludes that these reverse spillovers into technological innovations are not significant. To contrast, Li et al. (2016b) identify that there is significant difference in OFDI spillovers from east to western China with the effects being more limited in the west. Furthermore, R&D and human capital have much greater effects than OFDI indicating that these are critical channels for China to progress. Another is the OFDI effects in both short and long run, Yang et al. (2011) identifies that the results are regional with the level of development. This view is supported by Bruce and Chang (1991) and Rudy et al. (2016) that the heterogeneous nature of firms and regions in their technology capacities determines if OFDI spillovers are significant.

The Chinese government plays an important role in technological development in providing the necessary institutions to support development. Many developing countries suffer from institutional constraints that either limit possibilities or encourage to look abroad. (Luo et al., 2010; Child and Rodrigues, 2005). Such institutions including rule of law, enforcement of contracts, IP protection, capital controls and inability to control corruption may discourage development (Nolan, 2005). Partially, to overcome these barriers, government provides financial support for OFDI (Taylor, 2002; Rui and Yip, 2008) and overseas opportunity intelligence gathering (Luo et al., 2010). We ask, what can the Chinese government can do to with allocation of resources for scientific research to maximize the impact of OFDI spillovers? To address the gaps in technology firms can introduce frontier technology to boost innovation (Coe et al., 2011) and combine R&D with absorbed technology to create new technology (Osano and Koine, 2016). This presents a problem, resource allocation where both are costly. Factors such as resident preference, frontier technology distance, the development of the market, R&D efficiency also affect the decision of R&D (Osano and Koine, 2016; Cardenas et al., 2018; Piperopoulos et al., 2018).

Technology improvement is the core of economic growth (Romer, 1990). Core to growth is technology development through scientific research- applied research and basic research (Gulbrandsen and Kyvik, 2010; Henard and McFadyen, 2005). There are many empirical studies proving the advantages of public-funded basic research despite the limitations of methodology (Arrow, 1972; Nelson, 1959; Park, 1998). It is complementary for market failure and can boost technological innovation in the whole system (Nelson, 1995). Since the cost of basic research is high and the time before the appearance of outcomes is long, private sector is discouraged to invest in it. Taxpayers are only willing to finance basic research when it produces significant social returns (Nelson, 1959). One empirical research proves the higher social welfare resulted from basic research financed by private sector (Rosenberg, 1990). Thus, this research focuses on the role of government in conducting basic research to improve the overall technology absorptive capability for better absorption and use of foreign technology.

Between basic and applied research, there is competition for resources (Park, 1998; Akcigit et al., 2016). A limitation for the spread of the basic research is distance (Narin et al., 1997). Furthermore, the choice between basic research and applied research within a country or a firm based on technology gap (Rosenberg, 1990; Belenzon, 2006; Lai et al., 2006; Ha et al., 2009). Belenzon (2006) demonstrates that these types of research should be technological innovation complementary to cover frontier technology distance. One recommends that when the technology gap is relatively small, the government is responsible for more investment into basic research such as increasing the recruitment of higher education (Ha et al., 2009). Therefore, as frontier technology gap is a crucial factor influencing the technology capabilities including absorptive capacity and innovative ability, it constraints the OFDI spillovers’ and scientific research’ s impact on technological innovation. Furthermore, because basic research can increase the general stock of technology which strengths technology capabilities, the efficient amount of basic research can affect OFDI spillovers.

Since the government is the driving power for Chinese OFDI and plays an important role for the investment of basic research. It can take advantage of its related policy to maximize the technological benefit of OFDI spillovers. The primary goal of this research is to find the threshold effect of technology gap influencing OFDI spillovers’ impact on technological innovation. Then, on basis of the threshold, provinces can be divided into big technology gap group and low technology gap group to find out the political implications of scientific research for better use of OFDI for the acquisition of advanced technology and the creation of new technology. Thus, local authorities can apply to their own conditions when giving support to OFDI. It can still be a useful indication for local firms within a province since their resources are based on its location. By horizontal comparison with other firms in similar or related industries in the region, they can assess their own conditions about whether to invest abroad or not instead of blindly following the trend. A review of the most recent literature relevant to FDI and R&D is summarised in Table 1.

TABLE 1

Table 1 - OFDI and innovation review of the recent literature

Study	Method	Time	Sample	Region	Outcomes
Acs et al. (2002)	OLS	1982	8,074 commercial innovations	125 US metropolitan	Patent are a reasonable proxy for innovation, however, silent economic value to economy.
Borensztein et al. (1998)	2SLS and 3SLS	1970–79, 1980–89	1380	69 Developing countries	Developing countries FDI is an important tool for the transfer of technology and contributes economic growth in developing countries.
Braconier et al. (2001)	OLS, fixed and random effects	1978 -1994	217	84 Swedish firms	There is a strong positive relationship between OFDI and technology spillover effect.
Buck et al. (2006)	Probit and Tobit	1998-200.	5,861 foreign-invested, 7,697 Chinese firms	China	Technological innovation can be boosted by IFDI with a positive consequence on economic growth.
Coe and Helpman (1995)	OLS and WLS	1976-1989 excl. 1980	4,000 plants	Venezuela	That FDI/FII does not lead to technology spillovers

Study	Method	Time	Sample	Region	Outcomes
Comin and Hobijn (2004)	Pooled and fixed effects	1788–2001	23 countries and 25 technologies	23 industrial Countries	Human capital and income have a positive effect on technology adoption.
Lee (2006)	Dynamic OLS	1981-2000	320	16 OECD countries	The IFDI effects on international knowledge spillovers.
Li et al. (2016b)	Fixed effects threshold	2003- 2013	290	29 Chinese provinces	OFDI benefits of reverse knowledge spillover when the technology gap between a province and MNEs' host countries. Double-threshold effects of technology gaps.
Pavitt et al. (1987)	OLS	1945-1983.	4000 innovations	UK	U-Shaped relation between firm's size and innovation output.
Huang et al. (2012)	Fixed effects threshold	1985-2008	696	29 Chinese provinces	Double-threshold effects of regional innovation on productivity spillovers from FDI.
Tan et al. (2016)	Pooled mean group and mean group	1986-2011	128	8 ASEAN countries	Both IFDI and outward OFDI have a positive impact on the gross domestic investment.
Wang et al. (2016)	Fixed effects threshold	2000 -2011	360	30 Chinese provinces	The FDI technology spillover has two threshold effects of the technology gap in China.
Zhou et al. (2019)	FGLS	2004-2014	341	31 Chinese provinces	The relation between OFDI and domestic innovation is positive in developing countries but negative in emerging markets.

3 Hypotheses, theoretical framework and methodological approach

The three questions above map directly to the three hypotheses to test, namely:

1. *Chinese OFDI boosts domestic technological innovation.*
2. *That OFDI spillover generates a rate of technology innovation that is dependent on an absorptive capacity threshold being met within a geographic region.*
3. *That there are distinct joint impacts from basic and applied research and OFDI, on technological innovation, in the context of regional differences with respect to technology gaps.*

These hypotheses, if the evidence supports them, infer that OFDI has a material benefit with regards to technological innovation. Furthermore, that the degree of up take is dependent on the absorptive capacity of the provinces, demonstrating that the technology gap needs to be sufficiently wide, however not overly so to drive development and that it needs to be supported by both basic and applied research.

We develop three models to test these claims and subsequently imply some policy implications. However, we acknowledge that our initial hypothesis 3 requires a subsidiary test component that we discuss later. These models are based on the transformational process of less-developed countries in terms of technology introduction, absorption and innovation (Romer, 1990; Coe and Helpman, 1995).

3.1 Hypothesis 1 (H1): Chinese OFDI boosts domestic technological innovation

There is a presumption in the first hypothesis, that Chinese firms can absorb all the technology quickly, efficiently and deploy it effectively to increase innovation. This depends on the infrastructure, current technology levels, human capability and, willingness to learn and develop (Bitzer and Kerekes, 2008; Li et al., 2016a). These investigations adopt similar IFDI spillover methods and theories such as for technology (Coe and Helpman, 1995), and the LP model (van Pottelsberghe and Lichtenberg, 2001) for instance to analyse OFDI (Wang et al., 2016; Li et al., 2016; Piperopoulos et al., 2018). Although some of these studies identify that significant technology gaps are likely to moderate the effects of OFDI (Wang et al., 2016; Li et al., 2016a), the data in these studies is somewhat historical and potentially less applicable in today's environment, particularly in the Chinese provinces. Intuitively, one would consider that until a region has enough development in terms of both human and technological capital then that region's ability to absorb is somewhat limited. This leads us to the next hypothesis.

For the view that Chinese OFDI boosts domestic technological innovation, we need to observe that a measure of technology advancement has a significant positive relationship with OFDI whilst controlling for inward investment, R&D, human development and net exports at a provincial level over time (Coe and Helpman 1995). Following Griliches (1979), Hall and Ziedonis (2001) and Acs et al. (2002) and the general trend in the literature, we use the proxy of the intellectual property (IP) measure (authorized patents). A core driver for IP is domestic R&D (RD) supported by human capital development (HC) and the three channels for international spillovers: IFDI, import (IM) and export (EX) (van Pottelsberghe and Lichtenberg, 2001; Li et al., 2016b; Filippetti et al., 2017; Zhou et al., 2019). We take logs of all variables to form the linear model:

$$IP_{it} = \gamma_i + \alpha_1 RD_{it}^s + \alpha_2 IFDI_{it} + \alpha_3 IM_{it} + \alpha_4 EX_{it} + \alpha_5 HC_{it} + \beta OFDI_{it} + \epsilon_{it} \quad (1)$$

where the dependent variable is IP_{it} which is the number of authorised patents in province i at time t, $OFDI_{it}$ is the total inward foreign direct investment to China, EX_{it} is the total exports, IM_{it} is the total imports, $IFDI_{it}$ inward foreign direct investment from country i to China, HC_{it}

is the human capital level and RD_{it}^{s} is the stock of R&D investment, $OFDI_{it}$ is the total outward foreign direct investment from China.

As stated already, we use the flow of authorised patents as the proxy for the flow of technological development following Griliches (1979), Li et al. (2016a), Hong et al. (2019) and Zhou et al. (2019). This could be somewhat problematic in that patents are not necessarily of the same technological benefit nor do they cover all development (Griliches, 1990; Arundel, 2001; Cuddington and Moss, 2001). This is especially when patent protection in the host country is somewhat in its infancy, therefore alternative methods such as secrecy may offer better protection (Griliches, 1979). The alternative is R&D expenditure which measures only the resources put towards development which may not account for beneficial outcomes. Furthermore, accounting practice may differ across firms and lead to inconsistent results. Although IP is potentially problematic as a proxy, it is from a primary source which is not reliant on differences in reporting. It likely to understate the level of development, thus amplifying the effect of the inputs. Many of these criticisms are overcome by Li et al., (2016a) and overall it is accepted in the literature as a reasonable proxy.

When it comes to R&D, then we use the depreciated stock of all accumulated R&D investments in a province at time t. following the normal description for R&D inventories as set out in Coe and Helpman (1995) and Coe et al. (2009), hence:

$$RD_{it}^{s} = (1-\delta)RD_{i,t-1}^{S} + RD_{i,t}^{e} \tag{2}$$

where RD_{it}^{s} is the R&D inventory in province i at time t, δ is the R&D depreciation rate and RD_{it}^{e} is the R&D expenditure in province i at time t. We normalise all R&D to 2006 prices. This implies that for a province to grow R&D inventory then $\delta RD_{it-1} < RD_{it}^{O}$. This presents a problem, although we know the investment per period, we do not know the R&D stock. Again following Coe and Helpman (1995), we use the calculated present value of R&D stock at $t = 0$ by:

$$RD_{i,0}^{s} = \frac{RD_{i,0}^{e}}{(g+\delta)} \tag{3}$$

where growth rate in R&D expenditures are calculated by $g = \left(\frac{RD_{i,T}^{e}}{RD_{i,0}^{e}}\right)^{1/T}$ and then rolling forward (3) above to calculate every year's total R&D investment stock. By summing the provinces per period it provides the Chinese total level of R&D investment stock, formally:

$$RD_{t}^{s} = \sum_{i \in I} RD_{i,t}^{S} \tag{4}$$

We construct OFDI using the two step process set out in van Pottelsberghe and Lichtenberg (2001), Hong et al. (2019) and Zhou et al. (2019). Firstly, the domestic OFDI related R&D capital stock is obtained:

$$OFDI_t = \sum_j \frac{OFDI_{jt}}{GDP_{jt}} RD_{jt}^s \tag{5}$$

where $OFDI_t$ is the R&D stock China obtains from its OFDI towards country j in year t and GDP_{jt} is the GDP of country j in year t. We translate nominal into real by dividing $OFDI_{jt}$ by P_{jt} . The RD_{jt}^s is the R&D stock of the country j at the time t, it can be obtained using the same method as above:

$$RD_{jt}^s = (1-\delta) RD_{j,t-1}^S + RD_{j,t}^e \tag{6}$$

where RD_{jt}^s is the R&D inventory in country j at time t, δ is the R&D depreciation rate and RD_{it}^e is the R&D expenditure in country j at time t. Then the OFDI of the province is calculated by using the proportion of province OFDI stock relative to the domestic one.

$$OFDI_{it} = OFDI_t \times \frac{OFDIstock_{it}}{\sum_i OFDIstock_{it}} \tag{7}$$

The computations of inward FDI which is IFDI in this model, imports and exports are similar. Stock is better than flow for these tests because of its stability. The analysis of stocks is more suitable for research on the effect of IFDI spillovers in the longer term (van Pottelsberghe and Lichtenberg, 2001). As the Chinese firms investing in developed countries are more likely to be frontier technology seekers (Rui and Yip, 2008；Luo et al., 2010；Ramasamy et al., 2012), G7 countries (America, Canada, Britain, Germany, France, Italy and Japan) which are highly developed in technology are chosen as the targeted countries.

3.2 Hypothesis 2 (H2): That OFDI spillover is dependent on an absorptive capacity threshold

The absorptive capacity constrains the effectiveness of FDI. Absorptive capacity is a function of R&D investment stock and human capital (Cohen and Levinthal, 1990; Dussauge et al., 2000; Glass and Saggi, 1998; Mowery and Oxley, 1995). In equation (1), we control the heterogeneity by the fixed effects model. If the OFDI's coefficient for a province is significant and positive, then OFDI has an impact on technological development. To resolve this, we need to employ a threshold model to understand if thresholds exist and at what level. Equation (8) sets a threshold (TH) and determines the OFDI coefficient below and above that threshold. If a threshold exists and is significant in both coefficients then we check for two thresholds and so on (Wang, 2015; Li et al., 2016b). We employ the fixed-effects threshold model here (Hansen, 1999, 2000). The model is:

$$IP_{it} = \gamma_i + \sum_{m\in v} \alpha_{m,i,t}\, v_{m,i,t} \quad + \sum_{k=1}^{K+1} \beta_{k,i,t} TH_{i,t}\big(\theta_{k-1} < TH_{i,t} \le \theta_k\,\big) + \epsilon_{it} \qquad (8)$$

$$IP_{it} = \gamma_i + \sum_{m\in v} \alpha_{m,i,t}\, v_{m,i,t} + \beta_{i,t} OFDI_{i,t} \times TH_{i,t}\big(\theta_1 > TH_{i,t}\big) + \beta_{k,i,t} OFDI_{i,t} \times TH_{i,t}\big(\theta_1 \le TH_{i,t}\big) + \epsilon_{it} \qquad (9)$$

$$v = \{RD, HC, IFDI, IM, EX\}$$

$$TH = \{PG, HC, RD\}$$

$$\theta = \{-\infty, \theta_1, \dots, \infty\}$$

where $K + 1$ is the length of set θ, elements θ_1 ... are threshold parameters, PG is the productivity gap and TH is the threshold variable computed by the Hansen methodology. Note that if RD or HC is the threshold variable then it does not appear in the linear part of the model. We use the three proxies for the technology gap, these being the productivity gap, human capital and R&D stock. For the productivity gap (PG), we follow Kokko (1994), Castellani and Zanfei (2003) and Hong et al (2019), which involves using real GDP per capita. For human capital, we follow Glass and Saggi, 1998; Zahra and George, 2002; Comin and Hobijn, 2004; Zhou et al., 2019 to measure the absorptive capacity. Meanwhile, the R&D effort, spending on training and the ability to hire a well-educated labour force indicates the resources that a firm has (Cohen and Levinthal, 1990; Glass and Saggi, 1998; Mowery and Oxley, 1995). We apply the productivity gap, R&D stock and human capital to observe if technological absorptive capacity has a threshold effect.

This is similar to the drivers for 'clustering' of similar firms in geographical regions that we have observed throughout the industrial age. These prior studies do not consider that there is some 'threshold' where the absorptive capacity rapidly increases once the 'foundations' for development are set. Naturally, this implies some form of motivation. To find what motivates and facilitates the technological innovation. We move to the next hypothesis.

3.3 Hypothesis 3 (H3): Regional impacts from research and OFDI, on technological innovation

Our approach is to utilise the thresholds from H2 to classify provinces into two groups, large and small gaps. This allows us to explain how absorptive capacity influences the absorption effect of OFDI spillovers. Furthermore, also how this effect influences the technological innovation incentive effect of basic research. A non-significant threshold does not necessarily imply thresholds have no effect. We should expect that a small technology gap would lead to lower acquisition of technology spillovers suggesting that the absorptive capacity is not being fully utilised (Cohen and Levinthal, 1989; Martínez-Senra et al., 2015).

Salter and Martin (2001) identify that scientific research including applied and foundational or basic research is core to moving technological innovation forward. As in Nelson (1959), the difference between applied research, focusing on practical inventions and product development, and basic research in its effects on absorption and innovation capacity indicates that basic research is the foundation for absorptive capacity. Therefore, as these two forms of research have different but joint effects and there is little in the way of recent research on these effects, we need to consider the relative roles of applied and basic research, so we add a subsidiary to this hypothesis to clarify the distinct and joint impacts.

Foundational or basic research tends to be riskier, more expensive and lengthy than applied research thus governments tend to conduct or fund this type of research with the intention of producing spillovers into the private sector[4] (Nelson, 1959). The government can take on much greater risks and deploy greater resources to attain research objectives. Therefore, the private sector tends to focus on applied research that it can turn into marketable intellectual property and profitable products arising out of the work of government. Basic research would be significantly curtailed if only left to the private sector, thus governments' have a role in promoting basic research for the benefit of society (Park, 1998).

Of course, such research depends on the constraints of infrastructural capacity, human capability, resource availability and the absorptive capacity of industry. As such, government needs to consider if its research agenda is enhancing or displacing private sector R&D through such constraints, particularly in the context of OFDI. Regional government authorities need to cognisant that human capital, the R&D infrastructure and ability to absorb technology impose on addressing the technology gaps with foreign countries.

We utilise the Arrow (1972) and Park (1998) model extended by Cassiman et al. (2002), Henard and McFadyen (2005) and Gulbrandsen and Kyvik (2010) to explore the impact of applied and basic research on knowledge accumulation in conjunction with the technological

[4] Examples are in Space exploration where governments took the lead and eventually, we will observe the commercialisation by the private sector. This also include military research stemming back to the basics of radar, sonar, GPS providing the foundations for much applied research. Much foundational medical research is government funded particularly in the areas of vaccines and genetics.

spillovers absorption effect and innovation incentive effect, to determine if the can improve the technological innovation capability of firms. The model specifies the interaction between applied and basic research, the models include the provincial government (state) investment, measures of infrastructure development (road pavement) and per capita GDP to determine the province's technological development. We specify the model thus:

$$IP_{it} = \rho_{11} + \rho_{11}A_{it} + \rho_{12}A_{it} \times B_{it} + \rho_{13}H_{it} + \rho_{14}OFDI_{it} + \rho_{15}State_{it} + \rho_{16}pGDP_{it} + \rho_{17}pInf_{it} + u_i + v_t + e_{it} \quad (10)$$

where IP_{it} and $OFDI_{it}$ are as before, A_{it} and B_{it} is the applied basic research respectively. Basic Research is research that tries to expand the already existing scientific knowledge base largely on a theoretical basis whereas applied research solving real-life problems using scientific study, that is by developing practical solutions to real-world problems. The interaction term $A_{it} \times B_{it}$ represents the incentive innovation effect of basic research. We control for the number employed (H_{it}), provincial government investment in fixed assets $(State_{it})$, the per capita real GDP (GDP_{it}), and as a proxy for infrastructure the paved roads area $(pInf_{it})$ following Higón, (2016). The u_i is the provincial fixed effect and the v_t is the time fixed effect. However, we need to determine the level of applied research A_{it}, we do this by the process of Nelson (1959) by estimating the equation:

$$A_{it} = \rho_{21}IP_{it} + \rho_{22}B_{it} \times OFDI_{it} + \rho_{23}H_{it} + \rho_{24}OFDI_{it} + u_i + v_t + \mu_{it} \quad (11)$$

and $B_{it} \times OFDI_{it}$ indicates the absorptive effect of OFDI spillovers of basic research. Note that IP_{it} and A_{it} occur in both 10 and 11 creating an endogeneity problem that we solve by using three stage least squares.

4 Methodology and data

4.1 Econometrics approach

Our methodology combines the frameworks from the literature with the addition of some critical extensions to an extended and updated panel dataset (in Appendix A) to test the three hypotheses outlined above. In summary our approach is:

Collect the data from the various sources, combining it into a panel covering the timeframe and provinces with the inclusion of relevant controls, ensuring that it is consistent and reliable by performing summary statistics (see Appendix A) and other tests. We use unit root tests such as Levin, Lin & Chu (2002), Im, Pesaran, Shin (2003), Fisher ADF and Fisher PP, Maddala and

Wu (1999) and Choi (2001), to test for stationary in the panel data for each series. The next step is to determine the lag length for the hypotheses. We use the Akaike Information Criterion (AIC) to determine the selection of lags for all the dynamic time series analysis. Once we are satisfied with the combined panel checks then we can test the hypotheses.

Starting with H1, we test for the direct impact of OFDI on technological innovation in a province with and without lags. As this is a panel, we use the Hausman test, as suggested by Wu (1973), and Hausman (1978), to exclude pooled and random effects. If this is the case, then this implies that H1 is more suited to the fixed effects analysis.

Moving next to H2, were thresholds are important to our analysis, we apply the Hansen (1999, 2000) method to identify any threshold effects with their confidence bands for the threshold parameter. This provides a method of endogenously estimating the threshold level and its significance in a non-linear specification. The determination of thresholds is by beginning with identifying the first significant threshold then finding the second significant threshold and so on until there are no more significant thresholds.

Finally, H3 poses a problem of the simultaneous equations being over identified. This limits the possibility of using OLS, two stage least squares (2SLS), limited information maximum likelihood (LIML) and generalized method of moments (GMM), so directing us towards three stage least squares (3SLS), system GMM and/or Full Information Maximum Likelihood (FIML). This provides us with the linkages between variables whereas OLS etc. does not, so it increases the efficiency of the estimation. Therefore, we use 3SLS. An F-test on the first stage identifies if it addresses the issue of endogeneity. For consistency we expect an F-stat of greater than 10. We separate the provinces into two groups, namely, large and small technology gaps[5] as identified from H2. We expect that basic and applied research to have lag effects. We introduce controls for the one period and two period lagged values of applied and basic research respectively. In addition, we control for differences in the provincial and national economic factors, to consider the individual fixed effect and time fixed effects. We add to this hypothesis a subsidiary hypothesis to further explain the dynamics.

4.2 Data

We utilize a panel of 31 Chinese provinces covering the time period 2006 to 2016 including all the above variables sourced principally from the Chinese year book. We add in the controls

[5] The Technology gap is a measure of the level of technological development as benchmarked with the rest of the world, particularly the main trading partners.

such as employment, government investment, output and infrastructure. We normalize all prices to 2006 international US dollars. Prior to 2006 data for some provinces such as Xinjiang and Tibet is somewhat limited. Furthermore, this extends and updates the studies by Hong et al. (2019), Xia et al. (2016) and Li et al. (2016b) by using a more comprehensive dataset with significant methodological extensions. For a detailed analysis of the data sources and issues refer to the Appendix A.

5 Results

We report the results from our empirical analysis of the three hypotheses here in the same order as specified in the methodology section above.

5.1 Panel data tests and results

We report the results of the unit root test and AIC determined lags tests in Table 2. This identifies that none of the data exhibits a unit root. Furthermore, we identify that the lags between 1 and 3 are the most relevant for dynamic equation analysis.

Table 2- Unit Root and AIC results

Variable	Levin, Lin & Chu	Im, Pesaran and Shin W-stat	ADF - Fisher Chi-square	PP – Fisher Chi-square	Lags
IP	-12.25***	-1.51***	97.31***	132.02***	3
RD	-24.77***	-11.89	244.36***	292.60***	1
$IFDI$	-5.74***	-0.87	69.78	57.63	1
IM	-9.10***	-0.35***	93.72***	144.50***	1
EX	-27.86***	-6.38***	169.34***	102.18***	3
$OFDI$	-31.18	-5.11***	138.31***	153.75***	3
A	-21.36***	-11.28***	231.99***	275.67***	1
B	-23.11	-11.52***	234.62***	323.18***	1
GAP	-39.91***	-27.66***	418.05***	417.22***	1
HC	-6.39***	-1.82**	87.87**	35.83	1

Note: ***, ** and * indicate the level of significance at 1%, 5% and 10% respectively.

5.2 OFDI spillovers boosts technological innovation

Table 3 reports the OLS regressions, fixed effects and random effect models that test H1. We observe that the Hausman test confirms that the fixed effects model is preferable to the OLS/pooled and random effects models. R&D is the main driver of technological innovation as one would expect. Regarding OFDI, this is both positive and significant in both level and lag models indicating that OFDI has both an immediate and lasting effect on technological innovation, albeit small compared to R&D. This effect is observed across all provinces indicating that the Chinese government strategy of 'go-out' to the private sector has a materially positive impact on domestic innovation. Note that in the lagged OFDI models where OFDI plays a more significant role, than the R&D role, which is about 12% less indicating that OFDI is more important than R&D. This would lead us to consider that some level of R&D needs to be present for OFDI to be effective. We will explore this further in the next hypothesis.

Other than R&D and OFDI, all other variables are insignificant at the 5% level, only imports are significant but at the 10% level. This reinforces the point that R&D and OFDI are the significant determinants of regional innovation. Although domestic firms may observe and imitate imports (Coe and Helpman, 1995; Liu and Buck, 2006), this may not necessarily lead to increases in innovation. It is one skill to be able to copy and imitate, quite another skill to be able to create new knowhow and expertise that is exploitable. This is where absorptive capacity, the base level of skills and knowhow may come into play.

Regarding IFDI, the structure and controls in the Chinese economy may limit the effects of inward investment putting up barriers to offshore companies owning significant interests in Chinese innovation. Rather, the driving force may be more towards joint ventures and partnerships where the Chinese firms are seeking to transfer knowledge. These findings somewhat align to Piperopoulos and Wang (2018) in that the knowledge transfer and innovation performance are enhanced by OFDI.

One question could be that OFDI investments may not only render direct results on domestic innovation immediately but as one would expect, it may also occur over multiple subsequent periods. This leads us to explore and report on more dynamic variations in terms of the OFDI first and second lags, individually and collectively (columns 4 to 8). We note that in Table 3 that first and second lags individually (t-1 and t-2) are significant and positive and the lagged coefficients are increasing with time. This implies that OFDIs take time to be absorbed by the domestic economy. This leads us to test current and lagged combinations. OFDI with one lag is not individually significant, however, they are jointly significant in Table 4 and this continues for all combinations implying that OFDI has to be sustained over time to have a marked effect on domestic innovation. The policy implication is that government needs to have a sustained consistent outward investment policy over many years. This suits the Chinese economy whereas a government that may change every 3-5 years may experience inconsistency and limit the effects of such a policy.

TABLE 3

Table 3 - China's provincial effects on Innovation and OFDI

Variable	OLS	RE	FE (level)	FE (t-1)	FE (t-2)	FE (t,t-1)	FE (t,t-2)	FE (t,t-1,t-2)
RD	1.06^{***}	0.90^{***}	0.60^{***}	0.64^{***}	0.53^{***}	0.60^{***}	0.50^{***}	0.50^{***}
$IFDI$	0.10	0.05	0.05	0.04	0.05	0.04	0.05	0.05
IM	-0.15^{*}	-0.11	-0.08^{*}	-0.05	0.003	-0.05	-0.001	-0.01
EX	0.05	0.03	0.06	0.05	0.04	0.06	0.04	0.05
$OFDI$	0.05^{**}	0.04^{**}	0.11^{***}			0.05	0.02	0.04
$OFDI_{-1}$				0.09^{***}		0.05		0.04
$OFDI_{-2}$					0.11^{***}		0.11^{***}	0.12^{***}
HC	-1.36^{***}	-0.38	-0.38	-0.21	-0.29	-0.31	-0.32	0.26
C	-0.64	-2.37^{***}	1.47	-0.15	0.83	0.67	1.26	0.50
R^2	0.91	0.90	0.98	0.89	0.87	0.88	0.86	0.87
$F-statistic$	691.21^{***}	679.48^{***}	109.92^{***}	337.24^{***}	257.35^{***}	290.31^{***}	219.91^{***}	192.14^{***}
$Hausman\ Test^1$			17.91^{***}					
$Hausman\ Test^2$			30.92^{***}					

Note: ***, ** and * indicate the level of significance at 1%, 5% and 10% respectively. OLS= Ordinary Least-squares, FE= Fixed effects, RE= Random effects, Hausman Test^1= FE VS RE and Hausman Test^2= FE to OLS.

Table 4 - Joint significance test results

Wald Test	FE(t,t-1)	FE(t,t-2)	FE (t,t-1,t-2)
$F-statistic$	7.26^{***}	7.65^{***}	5.24^{***}
$\chi^2-statistic$	14.51^{***}	15.29^{***}	15.73^{***}

In Table 4, we observe that R&D is significant in all cases. However, if we take into account the level and lagged OFDI then the magnitude of the coefficient decreases indicating that OFDI has a role over time of about one quarter of that of domestic R&D. This supports the normative approach that both domestic R&D and sustained OFDI need to be present to increase domestic innovation.

IFDI and exports have little impact on innovation outcomes leading us to believe that foreign controlled investment and exports use productive capacity rather than innovative capacity. They have little domestic benefit other than the streams of income from exports and the labour force employment increases (Wei, 2010). As our focus is on OFDI, we shall leave that issue for other studies. Likewise, the coefficient of imports is negative but insignificant indicating little impact of imports on innovation. Although local firms can observe, study, imitate and upgrade imported products (Coe and Helpman, 1995; Liu and Buck, 2006), its spillover' effects on technological innovation are also influenced by absorptive capacity (Eaton and Kortum, 1996; Liu and Buck, 2006). This may contradict some political viewpoints that China's imitation and acquisition of foreign IP through these channels are the main drivers for their own innovation. Rather this activity may boost exports providing a flow of funds to domestic firms that they can employ into OFDI and R&D, this again is a subject for further investigation.

Finally, with human capital (HC), one would expect that human capital, in part, drives innovation output. Surprisingly, we find that this is not so in the presence of OFDI, regardless of lags. This seems to contradict the norms that domestic human development leads to improved outcomes over that where humans are just labour in a process. There are many studies into human capital development and its impacts, particularly in developing countries (Lai et al., 2006; Huang et al., 2012; Zhou et al., 2019). They indicate that there needs to be a base level of education, knowledge and knowhow to engage with R&D and the repatriation of technological innovation to be able to turn this into domestic innovation outputs. This implies some form of threshold of human development as a prerequisite for R&D, exploitation of repatriated technology and innovation outputs. We will discuss this under the threshold model next.

5.3 The technology absorptive capacity threshold effect

Our interest now turns to the capability of Chinese provinces to absorb technology and whether there is a threshold level applying to the productivity gap, human capital and R&D stock. If thresholds exist, then we should observe different innovation performances as a province crosses a threshold.

Table 5 reports the results of our single and double threshold tests. Following on from H1 and comments on human capital, we find that there is a single threshold indicating that there is some minimum level of human development necessary for effective absorption of technology from outside sources confirming what we suspected from H1. Note that there is only one threshold implying that a country, in this case China, needs to 'break though' by developing its domestic population's skills, expertise and knowhow though education and training. One could deduce that any developing country attempting to absorb foreign technology needs to attain some level of human development to exploit the technology effectively. This implies that government policy needs additional impetus towards education, training, knowhow retention and skills development to 'jump start' innovation (Li et al., 2016a; Zhou et al., 2019).

R&D also has a threshold indicating that there needs to be a level of R&D investment activity in prior years to build R&D capability. This implies that R&D tends to a critical mass where ideas, knowhow and people interact in networks to becomes efficient in producing innovative outputs. We observe this effect throughout history with clustering in such places as Silicon Valley (US) for Computational technology, Detriot (US) in the 1930's and the Midlands UK for vehicle development and Ruhr and Rhine valleys (Germany) for Heavy industry in the early part of the 20th century.

Table 5 – Thresholds Test Results

Threshold Variable	Threshold	θ_i	95% CI	F-statistic
Productivity Gap	1st	13.85	[13.19, 13.89]	18.53
	2nd	8.17	[7.550, 8.23]	8.29
Human Capital stock	1st	6.70	[6.69, 6.71]	59.09***
	2nd	6.25	[6.07, 6.57]	21.99
Research and Development Stock	1st	9.05	[8.67, 9.14]	57.04***
	2nd	13.60	[13.60, 13.62]	33.37

Notes: **, *** and * show significance at 1%, 5% and 10% levels respectively. 95% CI = 95% confidence interval.

In Table 6 we report the results from the interaction of a threshold variable with OFDI using the first threshold reported in Table 5. As before, R&D is a substantial contributor to the innovative outputs whereas IFDI, IM and EX are not. Although the threshold may not be significant the coefficients either side are implying that rather than being a point it is a transitional curve. When the productivity gap is wide, OFDI needs to make up the shortfall in to gain the necessary research outputs to increase productivity. We will discuss the potential for OFDI to crowd out innovation later. If the productivity gap is small then OFDI has effectively served its purpose in accelerating development to developed world standards. However, this relationship has a breakpoint where OFDI has much less effect on output, with a diminishing improvement in innovation as the gap is closed.

This naturally raises the question, is there a similar threshold for human capital stock and R&D as suggested by Table 5 when there is an interaction with OFDI? We observe a threshold in both cases (Table 6). Human capital has a pronounced difference in the coefficients indicating that OFDI has a doubled effect when human capital development is low than it does when human capital is high. Likewise, with R&D, although there is an effect, it is more limited. Note that both human capital and R&D coefficients are significant and in the case of HC, particularly pertinent in the presence of the R&D threshold. We can imply that both human capital and R&D are significant contributors to innovation in the face of OFDI. OFDI, as a policy, has a significant role in developing intellectual capacity and knowhow when reinforced with policies around human capital development and R&D activities. As the domestic HC and R&D matures then the effects of OFDI tail off and China becomes more self-reliant on its own capabilities. We observe this with the maturing of Chinese corporations now directly competing in innovation with developed nations. Exploiting this channel has and continues to be somewhat of a 'leg-up' for Chinese innovation.

In theoretical terms, one could draw parallels to the Solow growth model where more advanced provinces tend to have less to catch up thus reducing the spillover effect of OFDI in that geographic region (Wang and Blomstrom, 1992; Keller and Yeaple, 2009).

We observe a similar effect in India over a longer period. The complications in applying this inference to other developing nations is that in the case of British Commonwealth countries or were a prior war destroyed the industrial infrastructure. The late 19th and though to early 20th century saw IFDI activities driven out of the UK more to create cheaper materials for the home market. The late 20th century saw India now taking the lead in OFDI in the UK coming to some prominence in Information technology, manufacturing and raw materials production. The US, under the Marshal Plan (and others) saw much IFDI into Germany[6], Japan, South Korea and other SE Asian countries driven by political needs rather than economic reasoning. Again, Japan and South Korea conduct extensive OFDI across the developed world.

Considering these limitations, India could provide some parallels to China, being similar in population, educational distribution and in the same geographic region[7]. Both have followed similar paths in developing their export manufacturing, then building on that and in the case of India for example developing pharmaceuticals initially for its own population and then progressively competing on the world stage in both manufacturing and innovation. Similar parallels can be found in information technology, space and defence where India was initially a 'body shop' or manufactured for developed countries but now takes the technology lead in many international programmes through its OFDI efforts supported by improving absorptive

[6] Germany was already a heavily industrialised nation with world leading innovation. As with Japan, most of the industrial complex was destroyed and needed to be rebuilt, a lesson learnt from WW1.

[7] Note that China is a one party state with largely long term central planning and control whereas India has a democratic system where there is less control over the long term stability of government plans.

capacity (Iqbal et al., 2018). As with China, India now has a substantial R&D base in both academia, primary research and industry with applied research. Unlike some developing countries, both India and China have a reasonable level of political stability, although corruption and enforcement of property rights may impose limitations. We will leave further debate on this to future research.

Table 6 - The estimates of OFDI technology spillovers for single-threshold

Variable	TH=Productive gap	TH= Human capital	TH=R&D
RD	0.55^{***}	0.53^{***}	
$IFDI$	0.05	0.05	0.06^{*}
IM	-0.07	-0.05	-0.01
EX	0.02	0.08	0.09^{*}
HC	-0.26		1.17^{***}
$OFDI \times TH\ (TH \leq \theta_1)$	0.11^{***}	0.20^{***}	0.36^{***}
$OFDI \times TH\ (TH > \theta_1)$	0.10^{***}	0.12^{***}	0.22^{***}
Constant	1.96	-1.23^{**}	-4.69^{***}
R^2	0.86	0.85	0.23
$\boldsymbol{F-statistic}$	354.83^{***}	501.88^{***}	$4.76.27^{***}$

Notes: ***, ** and * show significance at 1%, 5% and 10% levels respectively.

5.4 OFDI, basic and applied research and, innovation technology gap.

The |Hypothesis tested now is: That there are distinct joint impacts from basic and applied research and, OFDI, on technological innovation, in the context of regional differences in technology gaps.

Using the results from H1 and H2, we divide the provinces into two classifications, those with a large technology gap and those with a small gap to compare the joint and distinct impacts of research on innovation when accounting for the gap. In Table 7, we report the results of running 3SLS for each classification of the provinces, with large and small technology gaps, to consider separately applied and basic research and total research, that being the interaction between applied and basic research. In addition, we consider OFDI separately and its interaction with basic research.

Table 7 – Role of applied research: 3SLS analysis of the grouping in the frontier technology distance

Dependent	Large				Small			
	Separate		Interaction		Separate		Interaction	
	$\boldsymbol{IP}$	$\boldsymbol{A}$	$\boldsymbol{IP}$	$\boldsymbol{A}$	$\boldsymbol{IP}$	$\boldsymbol{A}$	$\boldsymbol{IP}$	$\boldsymbol{A}$
$\boldsymbol{IP}$		0.26^{*}		0.55^{***}		-0.03		-0.35^{***}

$\boldsymbol{A}$	-0.45**				-0.71			
$\boldsymbol{B}$	0.94***				0.92			
$\boldsymbol{A \times B}$			0.29***				0.09***	
$\boldsymbol{OFDI}$	-0.03	-0.89***	0.01	-0.72***	-0.02	-0.90***	-0.002	-0.99***
$\boldsymbol{B \times OFDI}$		0.83***		0.65***		0.89***		0.99***
$\boldsymbol{H}$	1.01***	0.10	0.69***	-0.13***	1.29***	0.27***	1.22***	0.66***
$\boldsymbol{HC}$	-0.56***	1.03***	-1.10***	0.95***	0.37***	1.04**	-0.11***	2.72***
$\boldsymbol{STATE}$	-0.88**		-0.83**		-0.49		-0.51	
$\boldsymbol{pGDP}$	0.52***		0.35***		0.31***		0.30***	
$\boldsymbol{pINF}$	-0.04***		-0.04***		-0.01		-0.01	
$\boldsymbol{C}$	-0.00	-6.66***	4.03*	-4.65**	-0.00	-8.96**	-1.09	-19.22**
$\boldsymbol{R^2}$	0.93	0.94	0.95	0.93	0.88	0.94	0.94	0.93
$\boldsymbol{\chi^2}$	60511***	2182***	2959	1948	3136***	68675***	60510***	1930***

Notes: ***, ** and * show significance at 1%, 5% and 10% levels respectively. Large and small are separate data sets classified by the gap being either wide and narrow between the current Chinese technology and the world. Separate and interaction indicates that Applied and basic research are either separate variables with coefficients or they are combined into one interaction term with one coefficient. IP and A indicate that the dependent variable is IP – intellectual property and A is applied research. C is the intercept or constant.

In the simultaneous equation models, we consider the effect of the dependent variables IP and A on each other first. With large gaps IP negatively depends on A which is not the same with small gaps. On the contrary, A is positively enhanced by IP with large gaps and negatively with small gaps when we do not consider the rest of the research (B or A×B). We could infer that when the gap is large then possibly imported IP that is locally registered is then exploited for applied research. The more applied research activity there is the less that imported IP is needed and firms focus on improving their processes and knowhow in production. This theory could possibly be further enhanced if one considers that basic research in large gaps is a significant contributor to IP and this is the mechanism that drives more applied research (Nelson, 1959). Somewhere there may be an equilibrium growth path in research and its outputs that affect the interaction between IP and applied research. Although moderate in comparison, the interaction between applied and basic research has a positive outcome on IP. If a small gap is a situation where all research has matured, then the production of IP from the combination of applied and basic research is moderated inferring that it becomes increasingly harder to find new innovations that warrant IP and the focus becomes more on taking basic research through to it being applied and then into production. Possibly, the negative driver that IP has on applied research is that research is not as important when the gap is small.

Moving next to OFDI, such investment has a negative impact on applied research regardless of technology, however little impact on IP. However, when we take into account basic research, this negative impact turns positive possibly indicating that basic research is a significant driver of applied research regardless of the technology gap. This naturally leads us to create an additional hypothesis regarding basic and applied research with regard to OFDI and IP which we will explore later.

Next, accounting for the labour force and human capital, the role of the state and the state of the economy. An interesting observation is that employment (H) has a positive effect on IP in both large and small gap scenarios (approximately 30% more influence in small gaps) and contributes to small gap applied research. In contrast, human capital is negative in large gap contributions to IP and positive with applied research suggesting and possibly reinforcing the view that the large gap provinces largely import IP and then apply it though applied research. Once the domestic economy develops and the gap is small then human capital and employment contribute to both IP and applied research reinforcing the view that basic research has a material need for human capital development when the gap is wide (Kim, 1998; Girma et al., 2001; Hermes and Lensink, 2003).

Finally, considering the state and economy's role in the development of IP and applied research. As one would expect, growing GDP would have a positive influence with both large and small gaps, inflation only in large gaps. What seems to be a contradictory result to the norm is that state investment has a negative impact with large gaps and no impact with small. This seems to imply that the state somehow displaces new developments. However, if the theory that IP is imported holds when the gap is large, then the state could be involved in developing the basic and applied research capacity, which might go some way to explain the dynamics. When the gap is small then the state's role becomes irrelevant, again theorising, research capacity is most likely self-sustaining rather than needing government intervention relative to how it might have been done in large gap provinces.

5.4.1 Applied, basic research, their roles in technology gap

Extending H3, we consider the role of basic research as the instrument rather than applied research. We report the results in Table 8.

Table 8 - Role of basic research: 3SLS analysis of the grouping in the frontier technology distance

	Large		Small	
	Separate	Interaction	Separate	Interaction

Dependent	IP	B	IP	B	IP	B	IP	B
IP		0.05		0.85***		0.05		0.47***
A	-0.71***	0.53***		0.37***	-7.41	0.76***		0.70***
B	1.61***				9.71			
$A \times B$			0.29***				0.14***	
$OFDI$	-0.11***		0.08***		-0.26		0.003	
$A \times OFDI$		0.01***		-0.002		0.001		0.001
H	0.71***	0.02	0.64***	-0.67***	0.29	0.02	1.15***	-0.54***
HC	-0.45	-0.57**	-0.95***	-0.70**	-15.78	1.70***	-0.26	-0.42
$STATE$	-1.20**		-1.44***		0.79		0.44	
$pGDP$	0.42***		0.14**		0.14		0.25***	
$pINF$	-0.05***		-0.03**		0.07		-0.02	
C	-0.92	6.16***	3.20	8.73	100.16	-10.78***	-1.22	-4.92
R^2	0.89	0.93	0.95	0.89	-3.35	0.95	0.87	0.93
χ^2	2137***	2032***	2912***	1441***	329***	3463***	1300***	3069***

Notes: ***, ** and * show significance at 1%, 5% and 10% levels respectively. Large and small are separate data sets classified by the gap being either wide and narrow between the current Chinese technology and the world. Separate and interaction indicates that applied and basic research are either separate variables with coefficients or they are combined into one interaction term with one coefficient. IP and B indicate that the dependent variable is IP – intellectual property and A is applied research. C is the intercept or constant.

Following on from the Table 7 results and contrasting them with Table 8, applied and basic research have a magnified influence on IP, whereas employment and human capital effects are moderated when we do not consider interactions. When the instrument is basic research and is the dependent variable, then applied research, OFDI and human capital play a significant positive role whereas IP does not. Basic research has a significant role in developing IP (first column) and the mechanism for enhancing OFDI and human capital in IP development is though basic research. This potentially reinforces the argument that governments should encourage OFDI spillovers into the local economy and human capital development in the provinces to develop their economy and close the gap. Considering the interaction between applied and basic research, this is a driver for IP activity and IP with applied research has a significant positive impact on basic research. A counter-intuitive result is that, with a large gap, human capital has a negative impact on basic research whereas when considering Table 7 human capital plays a positive role in applied research. This would imply that provinces focus resources on applied research, however this has a negative impact on IP and basic research is a major driver, this presents a policy conundrum. To narrow the gap (IP) then basic research is a core driver, however that is not supported by human capital development. One could surmise that the specialist nature of basic research involves such a small part of the working population that the effects would be minimal.

5.4.2 Research analysis and discussion

When we consider the small gap, human aspects play no role in IP development however, human capital becomes significant in the context of basic research. Moreover, one could question the role of IP considering that it has no significant contributors, nor does it contribute to basic research. This implies that there is a structural change in the dynamics of the provincial economies suggesting that the threshold is likely to uncover differences. Taking the interaction model with the small gap then as with large gaps, IP and applied research have a significant positive impact, however, to a much lesser degree than wide gaps. It is important to consider how the interaction between applied and basic research contributes to IP development to a lesser extent than large gap provinces. Let's consider a scenario: a province with a large gap might find that human capital development is detrimental to basic research and decide to limit the investment. However, this may compromise both applied research and growth particularly when the gap narrows and the demand from basic research for human knowhow increases. There are substantial policy implications in the support of R&D with the effects from the underpinning resources to support both applied and basic research in a growing economy.

Some explanation of this basic research impact could come from Higón (2016). Although his was for the Spanish economy, there are some parallels in product pioneering in low to medium technology sectors. A developing country with a large gap may not have the necessary 'infrastructure' to conduct high-technology research and many developed nations focus on the Hi-tech industries, then this opens an opportunity to conduct basic research so pioneering the development of new products.

We concur with Czarnitzki and Thorwarth (2012) that basic research leads to other R&D, however we find that if applied research comes to the fore, then this has a detrimental effect on IP development. Furthermore, importing knowhow may not be good for IP development (Higón 2016). We observe that 'importing' (OFDI) has a negative effect on applied research as in Table 7 across the board, whereas if interacted with basic research then there is a positive contribution. In Table 8, we observe that OFDI has a negative impact on IP (separate) and positive in the interaction model. These effects are somewhat more limited that in Table 7. In all cases basic research is fundamental to driving technological innovation and not OFDI or applied research. This is most evident when the technology gap is large. Note however, that applied research is instrumental in driving basic research although it is detrimental to technological innovation.

As with Cassiman et al. (2002), we support the view that basic research with the *addition* of OFDI contributes to applied research and that applied research enhances basic research. This potentially complements the results of Henard and McFadyen (2005). Applied research is greatly enhanced by human capital in contrast to basic research and technological innovation, that human capital affects in a detrimental way. One could conjecture that Stern's (2004) view that lower salaries in basic research are less attractive. We may suggest that those best placed for basic research may seek alternatives with applied research when the gap is large. Maybe basic research is in its infancy when the gap is large. When the gap is small then basic research benefits from the human capital stock implying that the demand for highly skilled researchers needs to be matched with an equivalent supply for there to be gains in research output. As with Cassiman et al. (2002), the investment decisions of a firm in applied or basic research or, IP have a direct effect on the absorptive capacity. We find that the interaction between basic research and OFDI is the catalyst that drives both applied research and technological innovation. Policies that support firms conducting basic research in conjunction with a 'go-out' OFDI policy are more likely to benefit provincial, as well as national, growth.

6 Conclusion and policy implications

Our findings are that OFDI has both a national and provincial effect on the improvement to technological innovation if there is support by domestic regional policy. Although national governments may have an overall strategy, it can only work if regions (or provinces as in China) are able to adapt to the local conditions and circumstances. As such, regions will close the gap at different rates depending on policies expanding on the ideas set out in Piperopoulos et al. (2018). OFDI, by itself, has a negative effect on regional technological innovation. As such, repatriation of knowhow is reliant on the ability of the provincial, regional and national economy to absorb such knowledge and skills. Our conclusion is that for OFDI to be effective, it needs basic research as a key part of absorption into the local economy, therefore policy makers need to ensure that the necessary motivations and environment are suited to basic research exploiting OFDI. Failure to do so could lead to OFDI crowding out research.

An aspect of IP, OFDI and R&D is that it is not a linear relationship, rather a base level of provincial R&D and human capital must exist for the efficient and effective take up of such repatriated knowhow and absorptive capacity. This presents policy makers with a problem in that they must encourage investment into human capital and R&D. however, they must do that at a level that does not saturate the market and crowd out productive activities. As noted in the additional H3.1, applied and basic research have different demands on human capital and R&D depending on the threshold and distribution of research between applied and basic. Therefore, policies must be balanced between motivating domestic firms to 'go-out' with an OFDI strategy to appropriate technology knowhow whilst encouraging domestic R&D and supporting human capital development. OFDI must not be motivated to crowd out local development as we might observe in some of the provinces. Our threshold model enhances the viewpoints of Phene and Almeida (2008) with the addition of a regional perspective and thresholds.

Further to this it is necessary to consider the impact of OFDI spillovers and scientific research on technological innovation according to different absorptive capabilities. We demonstrate that technological absorptive capacity relies on the level of regional technological development, frontier technological distance and resources such as human capital and R&D stock. Policies need to account for regional variation. Our policy recommendations are that for large gap provinces, they should focus more on the investment into basic research to improve their technology levels and technology absorptive capability to ensure further development and better use of OFDI for technology spillovers. Provinces in the small technology group should consider the optimal allocation of resources for applied research, basic research and OFDI. Their technological development levels are initially relatively high, indicating their previous successful efforts in basic research. Therefore, they can try to find the balance between applied research and basic research to facilitate an efficient use of resources; they should not ignore the important role of basic research for long-run technological development and its positive impact on OFDI spillovers because it strengthens the absorptive capacity. Firms from those provinces should also be rational when considering conducting OFDI. They are supposed to comprehensively analyse the joint effects of basic research, applied research and OFDI spillovers according to their own development levels and conditions although it is difficult to do so, especially when the government is encouraging OFDI because it boosts overall technological progress.

As to the domestic policy regarding infrastructure, education, human development and R&D capability, we demonstrate that there are different thresholds where, at a provincial level, the ability to absorb efficiently is compromised when one or more elements is below that threshold. This is cogent with the view expressed in Baskaran and Chaarlas (2012), as policy makers need to consider the pre-existing R&D intensity (that includes human capital) to fully assimilate OFDI technologies. We add to the policy view in that policy makers must consider if their province or region is above or below the threshold. It could be quite feasible that a policy maker would progressively change their strategy, altering the disposition of 'investments' as they progress. As with China, and drawing parallels into the Indian sub-continent, such 'investments' need not only consider the national perspective, we demonstrate that policy makers need to account for regional differences in capability and not a 'one-size fits all' approach to OFDI and its supporting policies.

Although OFDI policies in China have been successful in short-cutting the route to developing world capabilities, it has drawn much criticism and resentment. Complaints about foreign ownership, state controlled commercial spying and IP theft to name a few. Recent trade restrictions imposed by America and others may have a long-term attenuating effect on OFDI and the 'go-out' policy. This may give other developing nations time to 'catch up' and exploit the opportunities that China has developed. One cannot separate international politics from domestic policy when it comes from trade and foreign investment. We leave that matter for future research.

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